

SHORT COMMUNICATION

Effects of non-native *Eucalyptus* plantations on epigeal spider communities in the northern Negev desert, Israel

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Abstract. Plantation forests are being planted at an increasing rate and account for 7% of the global forested area. The majority of planted forests are composed of exotic tree species, and *Eucalyptus* trees have become the most widely planted hardwood species in the world. While *Eucalyptus* plantations have economic importance, their role in native biodiversity conservation, especially in areas without naturally occurring forests, is little explored. In the present study, we assessed the impact on biodiversity of replacing natural semi-deserts with *Eucalyptus camaldulensis* plantations. The impact was evaluated by comparing epigeal spider communities of seven plantations with previously sampled communities of seven natural habitats in the northwestern Negev, Israel. In contrast to our assumptions, spider species richness was higher in *Eucalyptus* plantations compared to natural semi-deserts. However, substantial differences in species composition between the two habitat types were observed. Few species found in natural semi-deserts were sampled in the plantations, suggesting that *Eucalyptus* plantations cannot substitute for natural semi-desert habitats.

Keywords: Afforestation, spider, *Eucalyptus camaldulensis*, exotic plantation, land-use change

Today, the majority of planted forests are composed of exotic tree species, and *Eucalyptus* trees have become the most widely planted hardwood species (FAO 2006). However, the role of exotic *Eucalyptus* plantations in supporting native biodiversity outside Australia is controversial. Frequently, *Eucalyptus* plantations are considered as 'ecological deserts' (Brockerhoff et al. 2001), supporting fewer species than natural forests (e.g., Gardner et al. 2008) or natural open land habitats (Rodrigues et al. 2010; Gries et al. 2012).

Historically, the northern Negev desert in Israel is composed mainly of loess plains and steppe shrublands. Both semi-desert habitats are dominated by low and thick perennial shrubs, which are unique habitats for a variety of habitat specialists (Shochat et al. 2001). These natural habitats, however, have been mainly replaced by crop fields and more recently by exotic *Eucalyptus* plantations. Due to these anthropogenic influences, loess plains and steppe shrublands have become two of the rarest and most threatened habitats in Israel (SPNI 2014). While species richness and abundance of spiders has already been shown to be higher in natural semi-deserts than in crop fields (Pluess et al. 2008), little is known about the value of *Eucalyptus* plantations for spiders in this region. In the present study, we assessed the impact on species richness and abundance of spiders of replacing natural semi-deserts with *Eucalyptus camaldulensis* (Dehnh.) plantations in the northwestern Negev, Israel.

Spiders were sampled in seven *Eucalyptus camaldulensis* plantations. The sampled communities were then compared to spider communities sampled in seven natural semi-desert habitats by Pluess et al. (2008). The geographic locations of the *Eucalyptus* plantation sites were selected to vary as little as possible from the natural semi-deserts (Mann-Whitney-U test of latitudinal locations: $z = 0$, $p = 1$) as the latitudinal rainfall gradient has been shown to be correlated

with species richness and abundance in plants, small mammals, insects and spiders (Opatovsky et al. 2010; Segev 2010). The sampling sites were distributed over an area of approximately 15 km × 10 km in the northwestern Negev, Israel (Fig. 1) within the Irano-Turanian biogeographic region (Segev 2010).

The *Eucalyptus camaldulensis* plantations were located along dry riverbeds and were planted by the Keren Kayemeth LeIsrael - Jewish National Fund (KKL-JNF) 12 to 55 years ago. *Eucalyptus* trees have been planted in densities of approximately one tree per 25–56 m² on areas varying between 1.1 ha and 5.2 ha. The ground was mainly covered with leaf litter, interspersed with bare ground and vegetation. If present, the ground vegetation consisted of grasses and herbaceous species. All plantations were unmanaged and adjacent to other forest plantations and crop fields. The natural semi-deserts were located along dry riverbeds or on borders of military training areas. The vegetation comprised scattered perennial shrubs and geophytes, grasses and herbaceous species that appeared after winter rains, and some sites were interspersed with recently planted trees. For more detailed information about the natural semi-desert sites see Pluess et al. (2008).

Pitfall traps were used to sample the *Eucalyptus* spider community in order to be compared with the pitfall-trap sampling of Pluess et al. (2008) in the semi-desert habitat. Sixteen pitfall traps per site were used in *Eucalyptus* plantations, and 20 pitfall traps per site in natural semi-deserts. The traps consisted of plastic cups, which were 10 cm deep with an opening diameter of 9 cm. The cups were buried in the ground in such a way that the rim was level with the ground surface. Each trap contained 150 ml of 50% ethylene glycol with a drop of detergent as trapping liquid. As in Pluess et al. (2008), the traps in *Eucalyptus* plantations were opened for one week in January and for one week in February. The sampling dates were selected according to the high spider activity in this region during the first months of the

This publication is dedicated to Keren Embar.

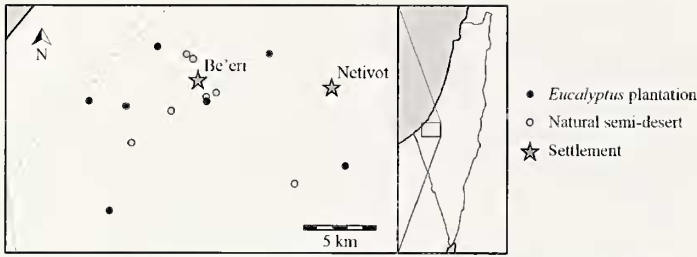


Figure 1.—Distribution of the 14 sampling sites in the northwestern Negev, Israel. Circles depict sampling sites.

year (Gavish-Regev et al. 2008). Spider communities in *Eucalyptus* plantations were sampled in 2011 and compared to the spider communities sampled in natural semi-deserts in 2007 (Pluess et al. 2008). For each site, the captures of both sampling sessions and all traps were pooled prior to analyses. We identified all individuals to family level and adult individuals to species or morphospecies level. The nomenclature followed Platnick (2013). Voucher specimens are deposited in the Arachnid Collection at the Mitrani Department of Desert Ecology, Ben-Gurion University of the Negev and in the National Arachnid Collection at the Hebrew University of Jerusalem, Israel. Only adult individuals were used for the statistical analyses.

Species-accumulation curves were used to compare species richness among habitats using rarefaction (Gotelli & Colwell 2001). Because pitfall traps were pooled prior to identification, an individual-based rather than sample-based approach was used for rarefaction. The implemented algorithm was based on a log Gamma function (Krebs 1989). The estimated mean and standard errors were used to estimate 95% confidence intervals. A significant difference in the total observed species richness of one habitat type was inferred if it fell outside of the 95% confidence interval of the other habitat type. An average of first-order Jackknife (Jack1) (Burnham & Overton 1978), first-order Chao (Chao1) (Chao 1987) and ACE (Abundance-based Coverage Estimator; Colwell & Coddington 1994) were used to estimate true species richness for each habitat. The species coverage of each habitat was assessed by calculating the number of observed species as a percentage of this estimate (Lobo 2008). Analyses of similarities (ANOSIM) were performed on the basis of Horn-Morisita similarities to test for significant differences of spider species composition between the two habitat types ($R = 0$ indicates complete similarity, $R = 1$ indicates complete dissimilarity). Nine morphospecies (singletons and doubletons) were omitted from ANOSIM because the taxonomic identity of individuals sampled in the two habitat types was unclear (see species with “?” in the occupancy columns in Appendix 1). Horn-Morisita similarities of transformed data were used to account for different sample sizes (Chao et al. 2006).

Rarefaction curves and the Mann-Whitney U test were performed using PAST (Hammer et al. 2001). The remaining analyses were performed using R (R Development Core Team 2012). We used the “fossil” package (Vavrek 2010) to calculate all richness estimators and the “vegan” package (Oksanen et al. 2010) to calculate ANOSIM.

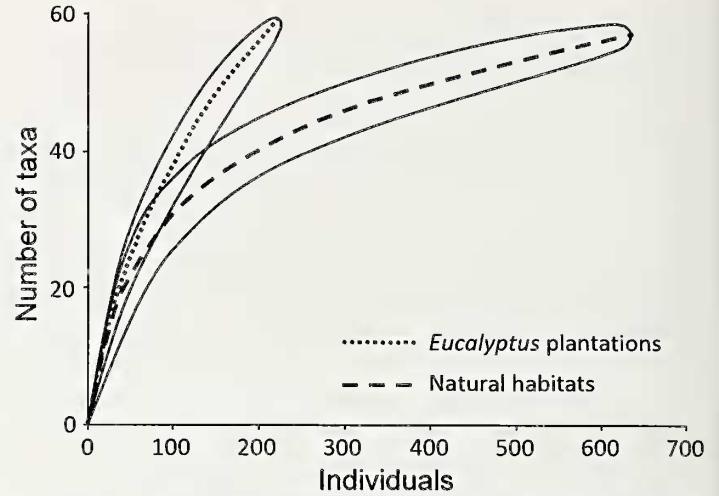


Figure 2.—Individual-based rarefaction curves for spiders in *Eucalyptus* plantations and natural semi-desert. Solid lines indicate 95% confidence intervals.

A total of 327 spiders were sampled during 1407 trapping days in *Eucalyptus* plantations. The 210 adult individuals belonged to 59 species in 21 families. In comparison, Pluess et al. (2008) sampled 1008 spiders during 1820 sampling days in surrounding natural semi-deserts. The 642 adult individuals belonged to 58 species in 16 families (Appendix 1). Rarefaction curves and coverage suggest significantly higher species richness in *Eucalyptus* plantations than in natural semi-deserts (Fig. 2, Table 1). In contrast, activity density was more than twice as high in semi-deserts compared to *Eucalyptus* plantations (Table 1).

The ANOSIM revealed significant differences of spider communities in *Eucalyptus* plantations and natural semi-deserts ($R = 0.573$, $P < 0.001$). In *Eucalyptus* plantations, 61.8% of the species were exclusive to this habitat and 62.9% of the species sampled in natural semi-deserts were not found in *Eucalyptus* plantations (Appendix 1). Only 20 spider species were found in both habitats. Three families Idiopidae, Oonopidae, and Sicariidae, were sampled only in *Eucalyptus* plantations (Appendix 1). In contrast, individuals of the family Zoridae were sampled only in natural semi-deserts.

The comparably high species richness in *Eucalyptus* plantations contradicts results of earlier studies, which observed lower species richness of Araneae and Scarabeidae in *Eucalyptus* plantations compared to natural open-land habitats (Rodrigues et al. 2010; Gries et al. 2012). Further, spider communities in *Eucalyptus* plantations differed strongly from those in natural semi-deserts. Fewer than half of the species were common to both habitats (Appendix 1) and the magnitude of calculated dissimilarities to natural semi-deserts is comparable to dissimilarities between natural forests and open-land (Kajak & Łukasiewicz 1994). This is in clear contrast to other results showing that *Eucalyptus* plantations in non-native regions mainly contain subsets of species sampled in natural habitats (Gardner et al. 2008).

Table 1.—Sampling effort, activity density, and species richness for spiders sampled in *Eucalyptus* plantations and natural semi-deserts. Column superscripts: ^a number of sampling days multiplied by number of intact traps; ^b mean number of juvenile and adult spiders per trap (\pm SE); ^c number of species observed; ^d number of species rarefied for 180 individuals (\pm SE); ^e number of species observed as percentage of estimated species richness (average Chao 1, Jack 1, and ACE).

Habitat type	Trap days ^a	Activity density ^b	S _{obs} ^c	S _{rar180} ^d	Coverage ^e
<i>Eucalyptus</i> plantations	1407	1.6 (\pm 0.1)	59	57.3 (\pm 0.9)	62.7
Natural semi-deserts	1820	3.8 (\pm 0.6)	58	39.7 (\pm 2.6)	80.2

These unexpected results may be explained by the exceptional role of *Eucalyptus* plantations in southern Israel. In the northern Negev, natural forests were absent for a long period of ecological time (Ginsberg 2002) and the majority of *Eucalyptus* trees are planted along dry riverbeds, increasingly replacing remaining natural semi-desert habitat (Amir & Rechtman 2006; SPNI 2014). This change in landscape structure can influence the local biodiversity in two ways: On the one hand, the afforestation with *Eucalyptus* trees transformed the once continuous natural semi-deserts into isolated habitat patches (Amir & Rechtman 2006). This increasing isolation of natural habitat may enhance the negative effect of habitat loss on remaining spider populations (Herrmann et al. 2010, 2012) by breaking continuous populations into metapopulations (Hanski & Gilpin 1991) or source-sink populations (Pulliam 1988) and increasing the negative effects of stochastic processes (reviewed by Simberloff 1994). Isolation effects may have led to a loss of species in natural semi-deserts, resulting in impoverished spider communities. On the other hand, the afforestation along dry riverbeds creates a well-connected web of plantations. This connectivity of plantations facilitates species dispersal (Caçada et al. 2013) and increases species richness in connected habitat patches (Bailey et al. 2010). The plantations, however, create “institutionalized landscapes”, different and foreign to the local vegetation (Amir & Rechtman 2006). They offer new structures and microenvironments, which are known to favor species that are not found in open land habitats (Uetz 1979). Instead of supporting species occurring in natural semi-deserts, *Eucalyptus* plantations may expand the natural distribution of forest species occurring in the central and northern part of Israel. Similar patterns have been observed in other parts of the Negev, where Mediterranean bird species immigrated from central and northern parts of Israel to establish populations in exotic coniferous plantations (Shochat et al. 2001).

Despite the relatively high species richness, the spider abundance in *Eucalyptus* plantations was comparatively low (Table 1). The low activity density could be linked to the biology of *Eucalyptus* trees. *Eucalyptus*-produced biomass is mostly unpalatable to native organisms in regions where these trees have been introduced (Paine et al. 2011). As herbivorous and detritivorous fauna are major food sources for epigeal spiders (Foelix 1996), large amounts of biomass and energy produced by *Eucalyptus* are hardly transferred to higher trophic levels (Cordero 2011).

Even though *Eucalyptus* plantations and natural semi-deserts were sampled at the same time of the year, *Eucalyptus* plantations were sampled in a different year than the natural semi-deserts. Differences in climate between the years may have influenced the phenology of some spider species (Polis & Yamashita 1991), thereby biasing our habitat comparison. In arid ecosystems, rainfall is most likely to cause differences by stimulating plant growth, animal activity and reproduction (James et al. 1995; Langlands et al. 2006). In the present study, total rainfall during the sampling and three months prior to the sampling was much lower in the year of *Eucalyptus* plantation sampling compared to the year of natural semi-desert sampling (5 month total: *Eucalyptus* sampling: 149 mm; semi-desert sampling: 249 mm). Recent studies in arid ecosystems showed an increase of spider abundance in years with higher precipitation (Langlands et al. 2006). The low precipitation during the sampling of *Eucalyptus* plantations may therefore have contributed to the low spider abundance. Yet, no significant relationship between precipitation and spider species richness has been found (Langlands et al. 2006; Opatovsky et al. 2010). Hence, the lower precipitation is unlikely to explain the higher species richness in *Eucalyptus* plantations.

Despite the frequently cited assumption of being ‘ecological deserts’ (Brockerhoff et al. 2001), our results indicate a higher spider species richness in *Eucalyptus* plantations compared to natural semi-deserts. However, since spider community dissimilarities were high between the two habitats and only few semi-desert species actually inhabited plantations, *Eucalyptus* plantations cannot substitute for natural

semi-deserts. The continuing replacement of natural semi-deserts with *Eucalyptus* plantations may therefore lead to fundamental changes of spider communities in this region.

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Appendix 1.—List of taxa sampled in *Eucalyptus* plantations and natural semi-deserts. Values represent number of sites each taxon was sampled from. '?'s indicate unclear taxonomic identity within a family between the two habitats (e.g., within Dictynidae, Morphospecies 1 is either the same as or different from Morphospecies 2).

Family	Taxon	Occupancy in		
		<i>Eucalyptus</i>	Natural habitat	
Araneidae	Morphospecies 1	1	0	
Clubionidae	Morphospecies 1	1	0	
	Morphospecies 2	1	0	
	<i>Clubiona genevesis</i> (L. Koch, 1866)	0	2	
Corinnidae	Morphospecies 1	0	1	
Ctenidae	<i>Anahita</i> sp.	2	0	
Dictynidae	Morphospecies 1	1	?	
	Morphospecies 2	?	2	
Dysderidae	Morphospecies 1	1	0	
	<i>Dysdera</i> sp.	0	2	
	<i>Dysdera westringi</i> (O. P.-Cambridge, 1872)	1	6	
	<i>Harpactea</i> sp.	1	4	
	<i>Tedia abdominalis</i> (Deeleman-Reinhold, 1988)	2	2	
	<i>Tedia oxygnatha</i> (Simon, 1882)	0	1	
Filiistatidae	Morphospecies 1	2	4	
Gnaphosidae	Morphospecies 1	1	0	
	Morphospecies 2	1	0	
	Morphospecies 3	1	0	
	<i>Haplodrassus mediterraneus</i> (Levy, 2004)	0	1	
	<i>Haplodrassus morosus</i> (O. P.-Cambridge, 1872)	2	2	
	<i>Micaria corvina</i> (Simon, 1878)	4	4	
	<i>Micaria ignea</i> (O. P.-Cambridge, 1872)	0	1	
	<i>Micaria pallipes</i> (Lucas, 1846)	0	1	
	<i>Minosia spinosissima</i> (Simon, 1878)	6	1	
	<i>Odantodrassus nundulus</i> (O. P.-Cambridge, 1872)	0	2	
	<i>Talanites</i> sp.	0	1	
	<i>Zelotes laetus</i> (O. P.-Cambridge, 1872)	1	0	
	Idiopidae	<i>Idiops syriacus</i> (O. P.-Cambridge, 1870)	2	0
Linyphiidae	Morphospecies 1	1	?	
	Morphospecies 2	1	?	
	Morphospecies 3	1	?	
	Morphospecies 4	1	?	
	Morphospecies 5	?	2	
	Erigoninae 1	0	3	
	Erigoninae 2	0	4	
	Linyphiinae 1	?	1	
	Linyphiinae 2	?	1	
	<i>Alioramus pastoralis</i> (O. P.-Cambridge, 1872)	1	7	
	<i>Dicymbium</i> sp.	3	0	
	<i>Meioneta pseudorestris</i> (Wunderlich, 1980)	0	4	
	<i>Pelecopsis</i> sp. 1	0	3	
	<i>Pelecopsis</i> sp. 2	0	1	
	<i>Pelecopsis inedita</i> (O. P.-Cambridge, 1875)	1	0	
	Liocranidae	Morphospecies 1	0	1
		<i>Liocranum</i> sp. 1	2	3
	<i>Mesitolus</i> sp. 1	1	2	
Lycosidae	Morphospecies 1	2	7	
	Morphospecies 2	2	0	
	<i>Alopecosa albofasciata</i> (Brullé, 1832)	0	4	
	<i>Hogna</i> sp.	2	0	
	<i>Pardosa proxima</i> (C. L. Koch, 1847)	0	1	
	<i>Trochosa</i> sp.	0	1	
	<i>Xerolycosa</i> sp. 1	5	0	
	<i>Xerolycosa</i> sp. 2	1	0	
Oonopidae	<i>Opopaea</i> sp. 1	2	0	
	<i>Orchestina</i> sp. 1	1	0	
Philodromidae	<i>Thanatus meronensis</i> (Levy, 1977)	1	0	
	<i>Thanatus</i> sp. 1	0	1	
	<i>Thanatus vulgaris</i> (Simon, 1870)	1	2	

Appendix 1.—Continued.

Family	Taxon	Occupancy in		
		<i>Eucalyptus</i>	Natural habitat	
Salticidae	<i>Aelurillus aeringinosus</i> (Simon, 1871)	0	2	
	<i>Aelurillus gershomi</i> (Prószyński, 2000)	2	0	
	<i>Aelurillus kochi</i> (Roewer, 1951)	3	0	
	<i>Aelurillus politiventris</i> (O. P.-Cambridge, 1872)	0	1	
	<i>Chalcoscirtus infimus</i> (Simon, 1868)	1	0	
	<i>Pellenes</i> sp.	0	1	
	<i>Pellenes geniculatus</i> (Simon, 1868)	1	1	
	<i>Salticus propinquus</i> (Lucas, 1846)	1	4	
	<i>Thiyene</i> sp.	1	0	
Scytodidae	<i>Scytodes</i> sp.	4	0	
Sicariidae	<i>Loxosceles rufescens</i> (Dufour, 1820)	1	0	
Sparassidae	<i>Micromata formosa</i> (Pavesi, 1878)	2	1	
Theridiidae	Morphospecies 1	1	0	
	Morphospecies 2	1	0	
	<i>Enoplognatha</i> sp.	0	1	
	<i>Enoplognatha gemina</i> (Bosmans & Van Keer, 1999)	5	6	
	<i>Enoplognatha macrochelis</i> (Levy & Amitai, 1981)	0	5	
	<i>Euryopis episinoides</i> (Walckenaer, 1847)	0	1	
	<i>Steatoda albomaculata</i> (De Geer, 1778)	1	0	
	<i>Steatoda paykulliana</i> (Walckenaer, 1805)	0	3	
	<i>Platnickina nigropunctata</i> (Lucas, 1846)	0	1	
	Thomisidae	<i>Ozyptila omega</i> (Levy, 1975)	0	2
		<i>Ozyptila patellibidensis</i> (Levy, 1999)	2	4
		<i>Ozyptila rigida</i> (O. P.-Cambridge, 1872)	1	0
		<i>Ozyptila</i> sp. 1	0	1
		<i>Ozyptila</i> sp. 2	0	4
<i>Ozyptila tricoloripes</i> (Strand, 1913)		3	2	
<i>Xysticus bliteus</i> (Simon, 1875)		0	2	
<i>Xysticus cristatus</i> (Clerck, 1757)		1	3	
<i>Xysticus edax</i> (O. P.-Cambridge, 1872)		0	1	
<i>Xysticus xerodermus</i> (Strand, 1913)		2	3	
Zodariidae	<i>Lachesana rufiventris</i> (Simon, 1873)	4	0	
	<i>Ranops expers</i> (O. P.-Cambridge, 1876)	0	4	
	<i>Trygetus sexoculatus</i> (O. P.-Cambridge, 1872)	3	0	
	<i>Zodarion nitidum</i> (Audouin, 1826)	1	2	
Zoridae	<i>Zoropsis lutea</i> (Thorell, 1875)	0	1	
Unknown	Morphospecies 1	1	0	
	Morphospecies 2	2	0	